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**Ball Diamonds as Habitat for Nests of *Cerceris fumipennis*
(Hymenoptera: Crabronidae): Comparisons among Three States**

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ABSTRACT: Surveys of baseball and softball diamonds for nests of the ground-nesting wasp *Cerceris fumipennis* were conducted between 2008 and 2011 in three states: Connecticut, Maine and North Carolina. A total of 1398 ball fields were surveyed, with roughly 22% of these positive for nests of the wasp. Nine percent of the fields had ≥ 15 nests and were therefore of practical use in a biosurveillance program for buprestid pests. Connecticut had the highest proportion of both positive fields and of fields useful for biosurveillance. Among fields with any number of nests, the two northern states had a significantly higher proportion with ≥ 15 nests. Characteristics of ball diamonds associated with the presence of *C. fumipennis* are discussed, and the advantages and disadvantages of using ball diamonds in a biosurveillance program addressed.

KEY WORDS: Biosurveillance, emerald ash borer, Buprestidae, *Agrilus*

The solitary, ground-nesting wasp *Cerceris fumipennis* Say provisions its nest almost exclusively with beetles in the family Buprestidae, allowing it to be exploited as a biosurveillance tool for the detection of buprestid arboreal pests: wasps are intercepted when they return to the nest from hunting trips, and their beetle prey collected and identified (Marshall *et al.*, 2005; Careless, 2009; Careless *et al.*, 2009; Careless and Marshall, 2010). The potential of these wasps as an early warning system for invasive beetles was developed in association with the establishment and spread of Emerald Ash Borer (EAB, *Agrilus planipennis* Fairmaire), an introduced species from China that has killed millions of ash trees (*Fraxinus* spp.) in the forests of eastern North America. Incipient infestations of EAB are challenging to detect because adults are typically active in the upper part of the tree, larvae are cryptic, and there is a time lag between initial attack by the beetle and the appearance of symptoms in the tree (Cappaert *et al.*, 2005; Wang *et al.*, 2010). Although a variety of detection methods are currently employed, each has unique limitations (Marshall *et al.*, 2010; Ryall *et al.*, 2011). The use of *C. fumipennis* as a survey tool for exposing incipient EAB infestations can add to the present detection arsenal and enhance efforts to contain populations of the pest.

Although *C. fumipennis* colonies can serve as natural buprestid monitoring stations (Careless, 2009; Careless *et al.*, 2009), the first step in any biosurveillance program lies in initially locating the nests. The wasps tend to live in loose aggregations, also called colonies, with each female individually maintaining a nest (Careless, 2009). Most species of *Cerceris* nest in flat or nearly flat soil of a particular consistency (Evans, 1971; Evans and Hook, 1986), and while female *C. fumipennis* accept a variety of

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substrate types (Evans, 1971), they prefer to nest near wooded areas in hard-packed, sandy soil that has sparse, short vegetation, is in full sun, and has some degree of human disturbance. Consequently, their nests are most often found in dirt parking lots, along the side of sandy roads and trails, in fire pits and campsites, and in playing fields such as baseball and softball diamonds (Evans, 1971; Careless, 2009; Careless *et al.*, 2009). We chose to focus on the last of these, primarily because campgrounds and picnic areas are often shaded, and it is difficult to systematically locate and search parking lots, roadsides, and trails. Ballfields offer additional advantages, for both wasps and for biosurveillance. One characteristic of ball diamonds that favors nesting by *C. fumipennis* is that the substrate is more predictable than in other habitats the wasps are known to occupy, such as dirt roads or campgrounds. Commercially available screened soil mixes are often used when a ball field is constructed or renovated. While proportions of the different components can vary regionally and according to intended use, the mixes typically contain a high proportion of sand, which makes them advantageous for *C. fumipennis*: a sandy substrate is easier to dig, cohesive at a slight depth, drains well, and allows air to circulate (Janvier, 1956). For humans, an advantage of using ball diamonds for biosurveillance is that the infield is small, compact, and bounded when compared to other *C. fumipennis* habitats, making it easier for one or two people to monitor nests. Monitoring can be difficult, for example, along a dirt road where there may be a number of nests, but these nests are distributed spatially along the road edge for several hundred meters. The infield on ball diamonds ranges from about 18 to 27 m², depending on the league and the type of game for which it was intended; the amount of unvegetated area behind baselines adds additional variation (HK Sports Fields, n.d.). Ball diamonds also lend themselves nicely to participation by citizen science volunteers, who may be intimidated by working in remote or forested locations. Ball diamonds are typically located in accessible environments, often with public facilities, and with safeguards against hazards such as poison ivy, Lyme disease, and fire ants. Ball diamonds in the southern United States are typically treated for fire ants (*Solenopsis invicta* Buren) on an as needed basis, which may benefit the wasps as well as humans. Although we have no direct evidence that fire ants feed on *C. fumipennis* brood or prey, these ants are opportunistic hunters known to feed on other fossorial insects (Tschinkel, 2006).

As an initial step in setting up regional biosurveillance systems, surveys were conducted in two northeastern and one southeastern state to find colonies of *C. fumipennis* on ball diamonds.

Methods

Surveys for the wasp were conducted in 2008–2011 in Connecticut (CT), 2008, 2009, and 2011 in Maine (ME), and 2009–2011 in North Carolina (NC), using similar protocol. Ball fields (i.e., baseball and softball diamonds) are distinctive in the aerial view offered by Google Earth, and this software was used to locate them for survey, to assess the degree of field maintenance and proximity to trees, and to plan a time efficient survey route. One caveat is that Google Earth imagery is updated on average every one to three years (Google Earth, 2012). Occasionally ball fields detected on the software, then, may no longer exist. Use of Google Earth was the primary method used in NC, and was used in combination with locating and inspecting school grounds in ME and CT. In all three states opportunistic finds of

schools and parks were investigated for the presence of ball diamonds. The timing of surveys was tailored to the weather and the activity period of the wasp. In NC, surveys were typically conducted from late May through July; in CT they were carried out from late June through August; in ME, surveys were usually conducted from mid-July to early September.

On arrival at a survey site, the sandy infield of the ball diamond was searched systematically for the characteristic nests of *C. fumipennis*: nest entrance about the diameter of a pencil, burrow descending vertically, and surrounded by a symmetrical rim of substrate (i.e., a tumulus). Female *C. fumipennis* with their distinctive facial markings could often be spotted at the nest entrance (see Careless, 2009; Careless *et al.*, 2009). The search for nests began by walking the edge of the infield, then proceeding in an ever decreasing spiral ending at or near the pitcher's mound. The number and location of nests were marked on a worksheet prepared for that purpose.

Statistics

Because different geographic sections of individual states were surveyed from year to year, data from each state for all years were pooled. Ball diamonds with nests of *C. fumipennis* were separated into two categories for analysis: those with 1–14 nests, and those with ≥ 15 nests. The latter category was considered suitable for subsequent collection of Buprestidae from foraging wasps (i.e., biosurveillance), as the greater number of nests resulted in a more time efficient return for the effort. Our choice of a 15 nest minimum is somewhat arbitrary, and can fluctuate depending on available time and human resources for monitoring the nests. In one site in Wake Co., NC, for example, the highest number of nests recorded was 14, but 61 buprestid beetles were collected from the wasps over a period of five days. In contrast, 50 beetles have been collected in large colonies in ME in 1.5–2.0 hrs.

To test differences among states for the relative frequency of positive fields (i.e., ≥ 1 nest of *C. fumipennis*), a Generalized Linear Model analysis of Type (1 = 1 or more nests present, 0 = nests absent) was performed using the GLIMMIX procedure in SAS (SAS Institute Inc, 2006). The model assumes Type having a binary distribution, which indicates that the logit = $\log(\rho/(1 - \rho))$, where $\rho = P$ (ballfield having ≥ 1 nest), is modeled as a function of state (CT, ME, NC). The relative frequency of ball fields with ≥ 15 nests of *C. fumipennis* was tested using a binary response variable and the logit = $\log(\rho_3/(1 - \rho_3))$, where $\rho_3 = P$ (ball field having ≥ 15 nests), is modeled as a function of state. Finally, among positive fields (≥ 1 nest), the relative frequency of fields with 1–14 nests and those with ≥ 15 nests was tested using a binary response variable and the logit = $\log(\rho_2/(1 - \rho_2))$, where $\rho_2 = P$ (ballfield having ≥ 15 nests conditional in fields having ≥ 1 nest) is modeled as a function of state. In all categories, pairwise Tukey's Studentized range test (*t*-tests) were used in post-hoc mean separation to group States with a similar response. Significance level was 0.05 for all tests.

Results and Discussion

A total of 1398 ball fields were surveyed: 338 in CT, 473 in ME, and 587 in NC. Slightly more than a fifth of these (22.5%) had at least one *C. fumipennis* nest present, but only 8.8% had more than the 15 nests considered as minimum for a field to be useful for biosurveillance. The relative number of positive ball fields (≥ 1 nest of *C. fumipennis*) was significantly different between states ($P < 0.0001$), ranging

from about 10% in ME to 39% in CT (Table 1, column C). Maine appears to be near the northernmost edge of the range of *C. fumipennis* (Scullen and Wold, 1969), which may account for the lower frequency of colonies for all fields surveyed in that state.

CT had the most ball fields useful for biosurveillance (i.e., ≥ 15 nests on a ball field): 22%, vs. about 5% in both ME and NC (Table 1, column E). However, if just positive ball fields are analyzed, the northern states (CT, ME) had significantly more that could be utilized in a monitoring program for pest buprestids (Table 1, column F). Northern states were also at an advantage in the maximum number of nests found on a single ball field; in CT the count was between 200 and 300, in ME about 300, and in NC the highest number of nests was slightly over 100. Currently, there are no obvious explanations for these differences among states, but relevant factors may include predators, parasites, prey size and abundance, soil moisture, and the availability of alternate nesting areas.

There was often more than one ball diamond at a given school or park; the average was two, with a maximum of nine. It was nonetheless uncommon for there to be a substantial number of nests on more than one ball diamond at a given site. For example, in Kennebec Co., ME, two seemingly identical ball diamonds were present at each end of a playing field, 100 m apart. In one diamond, a colony of 250–300 wasps has been present for four consecutive years, while no nests had ever been observed on the other. At the other end of the spectrum, occasionally a site that had three or four adjacent ball fields would have five or so nests on each field. While in total the site would meet the 15 nest minimum, moving between the ball fields for biosurveillance would be an inefficient use of time.

The number and location of *C. fumipennis* nests on a ball field is to some extent dependant on the timing of the survey (Fig. 1A, B). On a given field, nest number typically builds quickly after the wasps become active and peaks a week or two after the first females emerge (Careless, 2009). Nest number then slowly declines until the end of the active period, about six weeks later. Late emerging wasps, nest abandonment, nest usurpation, and both drought and prolonged wet periods add to variation in nest number (Careless, 2009).

Nests of *C. fumipennis* were typically found in open areas of the sandy infield, but were occasionally associated with objects such as base edges, pitching rubbers, electrical outlets, and sprinklers. Sandy areas devoid of vegetation in the vicinity of the ball field, such as batting cages and the areas around bleachers, also may have nests. In some ball diamonds, the nests were found exclusively within 25 cm of the grassy edge of the infield, while in adjacent diamonds the nests were scattered throughout the infield. We found that low lying areas of an infield where water may pool after a rain were unlikely to support nests; this concurs with the observation that prey are prone to decomposition in damp brood cells (Janvier, 1956).

In ball fields that are in active use during the summer, routine maintenance of the field (typically by raking or dragging) can disturb nests of *C. fumipennis*. If field maintenance occurs in the early morning or evening when wasps are resident, they should have no subsequent problem exiting their nest. If field maintenance occurs while a wasp is hunting or foraging, however, she may be unable to relocate her nest when she returns (Careless, pers. comm.). We have anecdotal evidence that *C. fumipennis* may have some degree of resilience to even larger scale disturbances. At one ball field in Wayne Co., NC, there were 83 *C. fumipennis* nests on 2 June 2011. The following day the field was resurfaced; the top few cm of the infield was removed

Table 1. Results of survey of ball fields for nests of *Cerceris fumipennis*.

	A No. fields surveyed	B No. positive (≥1 Nest)	C % positive (B/A)	D No. with ≥15 nests	E % with ≥15 nests (D/A)	F % positive with ≥15 nests (D/B)
Connecticut	338	133	39.3 a*	74	21.8 a	55.6 a
Maine	473	47	9.9 c	22	4.7 b	46.8 a
North Carolina	587	134	22.8 b	27	4.6 b	20.2 b
Overall	1398	314	22.5	123	8.8	39.2

* Results followed by the same letter are not significantly different at a 0.05 significance level.

and replaced. Subsequently, twelve nests were found on 6 June, and 21 nests on 1 July. This is a notable recovery, given that nest number typically begins to decline in July at this site, and that prior to the resurfacing, we ‘rescued’ (i.e., captured and removed to a different location) twelve of the females. When resurfacing occurred in three ball diamonds in ME prior to or after the conclusion of the flight season, little to no reduction in wasp number was seen. Field maintenance during the active season does eliminate any beetle prey that may be discarded around the nest entrance and are useful as part of the pest survey (see Careless *et al.*, 2009, p. 12); it also

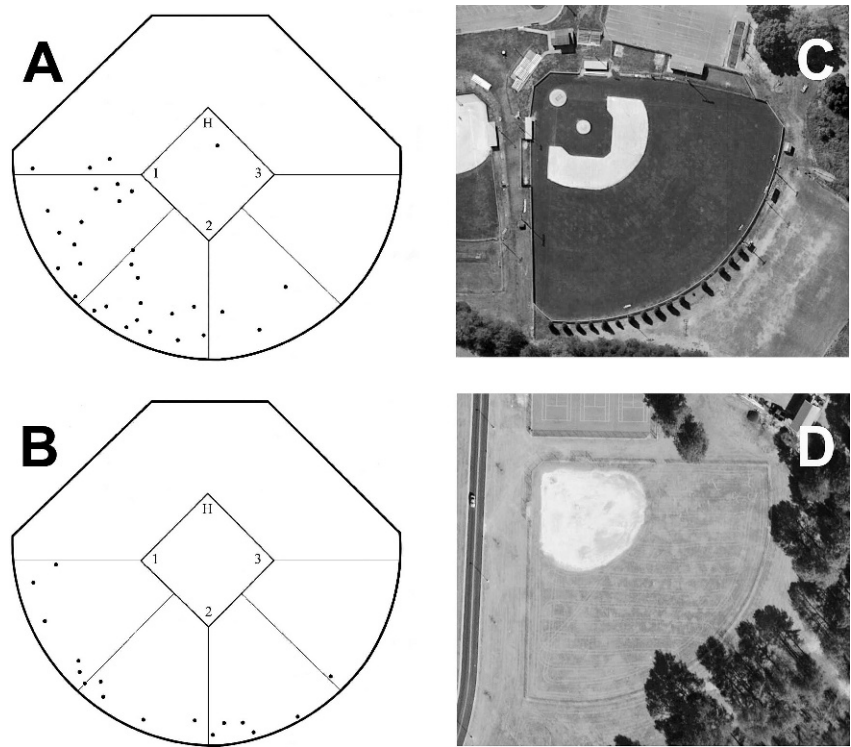


Fig. 1. Ball diamonds as habitat for *Cerceris fumipennis*. A) Diagram of number and location of nests on the infield of a ball diamond in Raleigh, NC, on 23 June 2009, located in a city park on a regular activity and maintenance schedule; each dot represents a nest, ‘H’ = home base; B) Same field on 14 July 2009; C) Highly manicured ball diamond without nests; D) A less well-maintained ball diamond in Wayne Co., NC that had 103 nests on 3 June 2011.

dictates that the equipment used in biosurveillance (such as flags or nest collars, see Careless *et al.*, 2009, Fig. 12) cannot be left overnight on the field.

Despite their resilience, wasps were rarely found on fields that were highly manicured (Fig. 1C); this category included ball fields associated with most colleges, large high schools, and sizable athletic parks. Such fields are additionally often fenced and locked. At the opposite end of the range, nests were seldom found in fields that had become completely overgrown with grass, a condition known to lead to the decline or emigration of a *Cerceris* population (Evans, 1966). Nesting aggregations of the wasp were most commonly found on ball fields that fell somewhere between these two extremes (Fig. 1D); this category includes practice fields (rather than playing fields), informal small town playing fields, and those associated with elementary and middle schools, where ball diamonds generally are not maintained during summer but are kept in good condition during the school year. Because nests of *C. fumipennis* were rarely associated with highly manicured ball fields, affluent geographic regions where baseball and softball have social significance are less likely to have fields appropriate for biosurveillance.

In an analysis of 24 sites in NC where there were ≥ 15 nests present on a field, there was no significant difference in the number of nests found on ball fields associated with schools vs. community parks (mean \pm SD of 35.2 ± 22.9 , $n = 13$, and 32.4 ± 15.8 , $n = 11$, respectively; $t = -0.341$, d.f. = 22, $P = 0.74$, pooled variance t -test). Schools, however, have fewer of the constraints that may hinder working with *C. fumipennis* on a ball field, namely, competition with ballplayers and maintenance of the field. The beginning of seasonal activity of *C. fumipennis* coincides fairly well with end of school year, when activity on school associated ball fields typically declines with the onset of summer vacation. In the northern states, wasp activity had greatly declined or ceased entirely by the beginning of the school year in September. In our experience, schools are cooperative with biosurveillance activities, and can be sources of volunteers to help monitor the site. Regardless of the location of a given field, its use for biosurveillance requires permission from relevant authorities, and the coordination of beetle collection activities with the activity schedule of the field. Because biosurveillance is a non-destructive method of sampling, permission to monitor colonies is rarely denied.

The observation that ball diamonds with *C. fumipennis* nests are often found in urban environments increases their value as a tool for detecting pest Buprestidae. Ash trees in urban areas are at high risk for establishment of EAB because the trees are often stressed from pollution, poor soil conditions, and lack of water (Nowak *et al.*, 2010). The same may be true for hosts of other buprestid pests of interest, such as the European oak borer (*Agrilus sulcicollis* Lacordaire), and the goldspotted oak borer (*Agrilus auroguttatus* Schaeffer). Nonetheless, natural colonies of *C. fumipennis* are not always well-placed for serving as the primary means of detecting pests (Careless *et al.*, 2009), and as we have shown here, sizable nesting aggregations are easier to find in some states than others. The development of mobile transplant colonies of *C. fumipennis* would greatly enhance their utility as a biosurveillance tool; research is currently being conducted in that area (Careless, 2009; Careless *et al.*, 2009).

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